Articles

Sea-Level Physical Activity and Acute Mountain Sickness at Moderate Altitude

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The effect of previous physical conditioning on young well-conditioned mountaineers in relationship to acquiring acute mountain sickness is controversial. Data show both increased and decreased effects on the incidence of altitude illness. How general tourists at moderate altitudes are affected is unknown. To determine the influence of sea-level habitual physical activity on the incidence of mountain sickness, we surveyed 205 participants in a scientific conference at 3,000 m (9,840 ft). A 36-item questionnaire was distributed to the subjects 48 hours after arrival at altitude. Their sea-level physical activity (SLPA) was measured by a published and validated instrument that included questions about patterns of work, sporting, and leisure-time activities. Acute mountain sickness was defined as the presence of 3 or more of the following symptoms: headache, dyspnea, anorexia, fatigue, insomnia, dizziness, or vomiting. Most of the respondents were male (62%) from sea level (89%) with a mean age of 36 ± 8.7 (standard deviation) years (range, 22 to 65). Nearly all (94%) were nonsmokers, and 28% had acute mountain sickness. The mean SLPA score was 8.0 ± 1.3 (range, 5.1 to 12.0). No statistically significant difference in mean SLPA scores was found between those with and without acute mountain sickness (8.1 versus 7.8), nor in the individual indices (work, 2.5 versus 2.4; sport, 2.9 versus 2.7; leisure, 2.8 versus 2.7). We conclude that habitual physical activity performed at sea level does not play a role in the development of altitude illness at moderate altitude in a general tourist group.

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Acute mountain sickness (AMS) is a symptom complex consisting of headache, dizziness, insomnia, and gastrointestinal complaints that occurs in 12% to 60% of travelers to altitude.[1,2] Although most studies concerning AMS and other related altitude illnesses have been conducted on small physically fit groups with exposure to very high altitudes, millions travel to moderate elevations, and AMS may develop in as many as 25%.[3,4]

The rapidity of ascent, the elevation attained, and underlying pulmonary problems have been identified as increasing the risk of symptoms developing.[1,3] The effect of physical conditioning on the development of AMS, however, remains unknown. Studies conclude that greater levels of aerobic capacity increase[5] or have no effect on the risk of AMS developing.[6,7] Others suggest that physically fit persons are better able to tolerate mild to moderate symptoms.[8]

We, therefore, studied a group of tourists traveling to moderate altitude to determine the association of sea-level habitual physical activity (SLPA) with the development of AMS and to determine whether SLPA can be used to predict persons at risk for altitude illness.

Subjects and Methods

The study group consisted of 205 adults attending a scientific conference at a Rocky Mountain resort located at 3,000 m (9,840 ft). Most (128 [62%]) participants were male; their mean age was 36 ± 8.7 years (standard deviation) (range, 22 to 65); 182 (89%) lived at sea level (below 1,000 m [3,280 ft]); 194 (94%) were nonsmokers; and 125 (61%) had at least one alcoholic drink after arrival. The mean body-mass index[9]—weight in kilograms ÷ height in m^2—demonstrated that the study group was representative of the general population in terms of body habitus (male = 23.7 ± 4.5; female = 21.1 ± 5.1).

The conference was chosen as one whose schedule required all participants to attend an early morning meeting within 48 hours of arrival, when the questionnaire could be distributed. Study personnel attended this meeting and distributed and collected the questionnaire as participants

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ABBREVIATIONS USED IN TEXT

AMS = acute mountain sickness
SD = standard deviation
SLPA = sea-level [habitual] physical activity
Vo_2max = maximum oxygen consumption

passed through the one available doorway. The survey instrument was completed by 96% of the persons attending the meeting, and data satisfactory for analysis were obtained in 99% of completed surveys.

Questionnaire

The questionnaire was designed to elicit data regarding demographics, level of habitual physical activity, and symptoms of AMS.

Sea-level physical activity was measured using an instrument developed by Baecke and co-workers.[10] It is a compilation of constituent indices measuring activity at work, during sports, and during leisure time. Responses were assessed on a 5-point Likert scale—never, seldom, sometimes, often, always—except for two that asked for type of activity. The first was occupation, which was then coded into one of the three levels as defined by The Netherlands Nutrition Council.[11] Low-level work activity corresponded to clerical work, shopkeeping, teaching, and medical practice; middle-level activity corresponded to factory work and farming; and high levels of work activity included jobs such as construction work and professional sports. These are similar to occupational and physical activity classifications developed by other investigators.[12,13] In addition to job class, calculations of work activity included questions regarding the amount of time spent sitting, standing, walking, and lifting heavy loads and the amount of fatigue at the end of a workday.

Sports activity was compiled from questions concerning the type of sport and frequency, duration, and exertion while playing. Types of sports were divided into three categories.[13] The lowest category, represented by sports such as sailing and bowling, corresponded to an average energy expenditure of 0.76 megajoules (MJ) per hour. The middle level corresponded to 1.26 MJ per hour and included tennis and swimming. The highest level included rowing and basketball and represented an average expenditure of 1.76 MJ per hour.

Leisure-time activity was distinguished from sports activity by asking questions regarding the amount of time spent watching television, walking, and cycling in absolute terms and in reference to others of the same age.

Acute mountain sickness was defined as the presence of three or more of the following symptoms after recent exposure to altitude: loss of appetite, vomiting, shortness of breath, dizziness or lightheadedness, unusual fatigue, insomnia, or headache. This definition is similar to that used by other investigators.[1,3,4,14-16] Participants were asked to respond yes or no to a question asking them if they had experienced any of the above symptoms since arriving at the resort.

Statistical Analysis

Participants were classified as having or not having AMS, and then demographic and activity variables were compared using the Student's *t* test for normally distributed variables and the χ^2 test for discrete variables.

An analysis of variance was used to study the mean SLPA scores between groups of participants with differing numbers of accumulated symptoms. Forward-stepwise multiple logistic regression was used to examine the independent effect of SLPA, adjusting for age and altitude of permanent residence, both of which have previously been shown to be associated with the occurrence of AMS.[2] Sea-level physical activity was evaluated both as a continuous response attribute and a grouped variable; age was always incorporated as a continuous response; permanent residence was dichotomized into sea level (below 1,000 m) and above sea level. All calculations were performed using the SAS statistical software package. Variations are expressed as standard deviations. Associations were considered significant if they achieved a probability level of less than .05.

Results

Of the study group, 28% reported having three or more symptoms and hence met the case definition for AMS. At least one symptom was reported by 73%, with headache being the most common (n = 120 [59%]). Insomnia (58 [28%]) and unusual fatigue (48 [23%]) were present in many visitors, but dizziness (35 [17%]), anorexia (28 [14%]), and vomiting (5 [2%]) were seen less commonly.

The distribution of SLPA scores is shown in Figure 1. The mean SLPA score was 8.0 ± 1.3, with values normally distributed around the mean according to goodness-of-fit tests. The individual components of SLPA scoring were as follows: mean work activity, 2.4 ± 0.3; mean sport activity, 2.8 ± 0.8; and mean leisure activity, 2.8 ± 0.6.

When SLPA scores were compared between those with and without AMS, no significant differences were found (Table 1). Mean SLPA scores for the two groups were 7.8 ± 1.3 and 8.1 ± 1.2, respectively. Similarly, no differences were found between the two groups when the constituent indices of SLPA were compared. Of note, however, is that the leisure-time index (time spent watching television, reading, and so forth) tended toward significance ($P = .06$).

To further investigate the association of SLPA with an increased number of symptoms defining AMS, a one-way analysis of variance was used. Figure 2 plots the mean SLPA scores stratified by the number of AMS symptoms. This analysis failed to demonstrate differences in the mean SLPA scores between these groups ($P = .64$, $R^2 = .01$).

Forward-stepwise multiple logistic regression also failed to show that SLPA, after adjusting for age and sea-level residence, was predictive of AMS developing ($P = .16$).

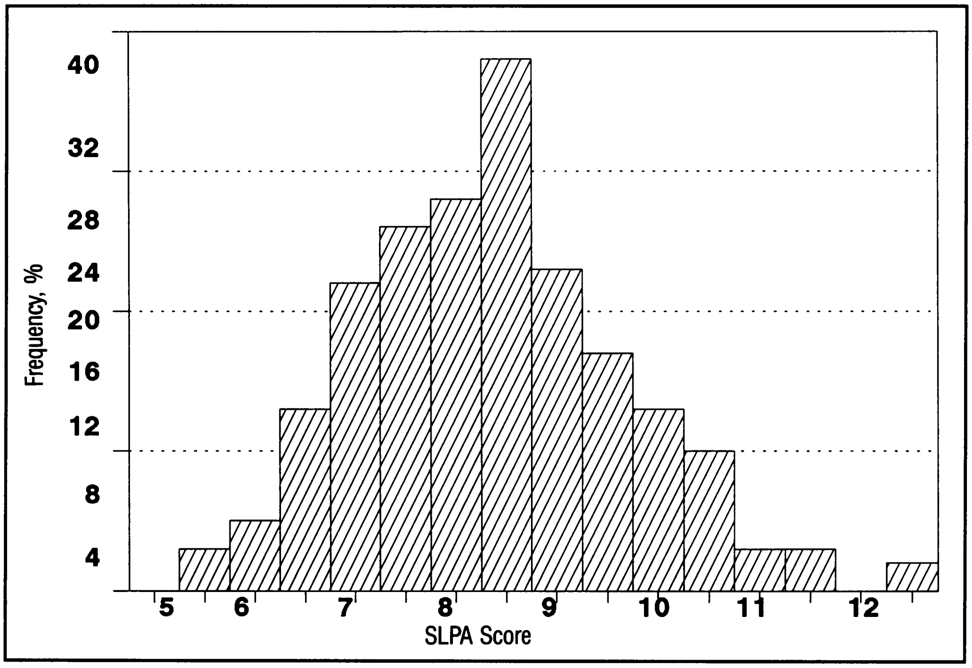

Figure 1.—The graph shows the distribution of sea-level physical activity (SLPA) scores in visitors to moderate altitudes.

Discussion

The main finding of this study is that there was no apparent association between sea-level habitual physical activity and the development of acute mountain sickness in the general population traveling to moderate altitude (3,000 m). This report represents the largest observation of persons who have a broad range of activity patterns at sea level and the influence of these fitness levels on altitude illness.

Despite Ravenhill's early observation that "young, strong and healthy men may be completely overcome [by AMS] while stout plethoric individuals . . . may not even have a headache,"[17(p315)] the precise effect of physical fitness on the development of AMS remains unknown.

In two studies, hundreds of persons in the Indian army who traveled to between 3,000 and 4,500 m (9,840 and 14,760 ft) were studied, and the investigators noted that AMS developed in all types of persons "without any

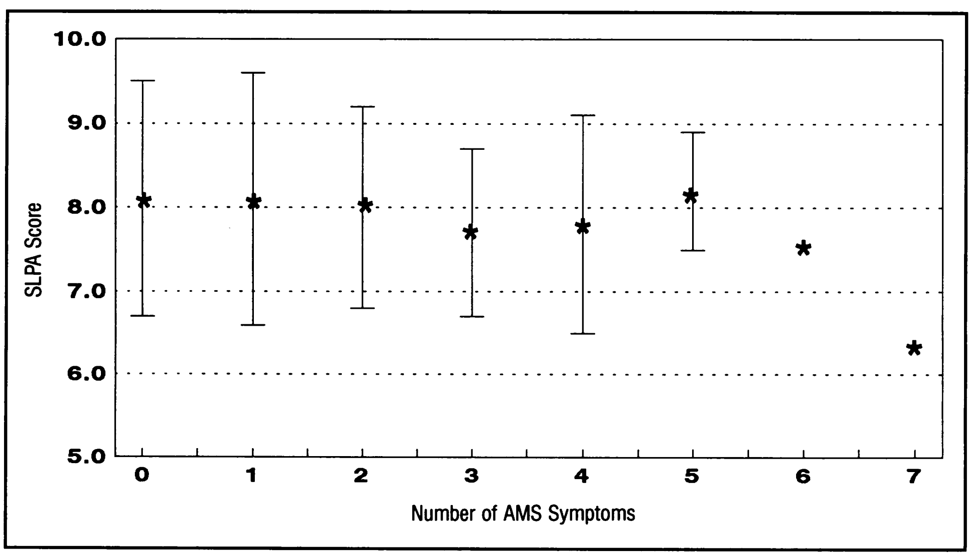

Figure 2.—The graph shows the distribution of mean sea-level physical activity (SLPA) scores by the number of symptoms of acute mountain sickness (AMS) in visitors to moderate altitudes. The asterisks (*) signify the means and the vertical lines the ranges (distribution).

TABLE 1.—*Mean Sea-Level Habitual Physical Activity (SLPA) Scores in Those Visitors With and Without Acute Mountain Sickness (AMS) at Moderate Altitudes*

SLPA Score	AMS	Non-AMS	P Value
Overall score	7.8	8.1	.15
Constituent scores			
Work	2.5	2.4	.09
Sport	2.7	2.9	.09
Leisure	2.7	2.8	.06

predilection for the obese."[2,18] No information other than weight was used to measure fitness. Previous work in a tourist population[3] and in a group of Japanese trekkers,[19] however, showed that persons who were obese had a higher incidence of AMS. Rennie has stated that AMS is not "in any way related to the state of physical training,"[6] whereas Hackett has observed that

> fit persons are better able to tolerate mild and moderate AMS. Persons struggling into camp each day because of their poor conditioning will often find even mild AMS unbearable . . . whereas more fit individuals might 'tough it out.'[8(p137)]

Yet, the direct effect of physical fitness has been only minimally studied, using maximum oxygen consumption (Vo_2max) on the development of AMS,[5,7] and these results are conflicting. In one of the studies, no correlation was found between predeparture Vo_2max values and the incidence of AMS in 17 marines at 4,500 m, but few of these persons had AMS because they took seven days to reach their destination.[7] A second study showed, however, that the levels of aerobic fitness as measured by the Vo_2max did affect the severity of AMS in 12 young men at 4,300 m (14,110).[5] Although both of these studies used a physiologic measure of fitness, they were limited to small groups of healthy young men.

Our report supports the results of others.[1,7] Because of the size of the group studied, we were unable to use precise markers of cardiorespiratory fitness such as the Vo_2max. We, therefore, measured fitness by using a detailed questionnaire specifically developed to study habitual activity levels as a measure of physical fitness in the general population.

Several authors have addressed the assessment of physical activity in epidemiologic studies and its relationship with physical fitness.[20-23] A consensus statement developed at the 1988 Toronto Conference on Exercise, Fitness, and Health stated that habitual physical activity influences fitness despite individual health status differences.[24] The National Heart, Lung, and Blood Institute found that survey methods using physical activity indices are associated with ten-year coronary heart disease rates. The indices are more sensitive in persons with high levels of physical activity than in sedentary persons.[25] A significant and positive correlation was found between treadmill performance and leisure-time physical activity and leisure-time physical activity and personal reports of sweating and dyspnea.[26] Finally, an investigator found that leisure-time physical activity correlated well with submaximal physical work capacity.[27] Although the questionnaire we used has not previously been used for altitude investigations, it has been shown to be valid, has good test-retest reliability, is nonreactive, and is easy and quick to have participants complete without help from interviewers. There are several other general surveys available for assessing physical activity,[28,29] as well as several quantitative history surveys,[30,31] recall surveys,[32,33] and diary methods.[34] Many of these instruments have been developed to study the effects of physical activity on heart disease, and they often focus on one aspect of physical activity, for example, leisure- or job-related activity. Because most of these require substantial amounts of time to complete, are focused on only one area of activity, or require a trained interviewer to administer, they were not selected for our study.

Although our results suggest that active persons are no more at risk for the development of AMS than those who are less fit, the number of persons in this active group was small. In addition, it is possible that the questionnaire is not sensitive to the extremely fit or elite athlete, therefore possibly invalidating our results in this group. A further limitation of the instrument is that no questions were asked regarding the specific activity undertaken at altitude. It may be that some persons may be more active at altitude, thus increasing the risk of AMS developing. Despite these limitations, we think the results can be applied to the general population of travelers visiting moderate altitudes.

Our findings that sea-level habitual physical activity is not associated with AMS and is not predictive of who will have mountain illness supports the fact that no one is immune from this disorder. This may help practicing clinicians when advising their patients regarding travel to moderate altitudes.

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REFERENCES

1. Hackett PH, Rennie D: The incidence, importance and prophylaxis of acute mountain sickness. Lancet 1976; 2:1149-1155

2. Singh I, Khanna PK, Srivastava MC, Lal M, Roy SB, Subtramanyam CSV: Acute mountain sickness. N Engl J Med 1969; 280:175-184

3. Honigman B, Theis MK, Koziol-McLain J, et al: Acute mountain sickness in a general tourist population at moderate altitudes. Ann Intern Med 1993; 118:587-592

4. Montgomery AB, Mills J, Luce JM: Incidence of acute mountain sickness at intermediate altitude. JAMA 1989; 261:732-734

5. Cymerman A, Jaeger JJ, Kobrik JL, Maher JT: Physical Fitness and Acute Mountain Sickness (AMS). Proceedings of the 1979 Banff Hypoxia Symposium (Abstr). Calgary, Alberta, Canada, Arctic Institute of North America, 1979, p 66

6. Rennie D: See Nuptse and die (Editorial). Lancet 1976; 2:1177-1179

7. Milledge JS, Beeley JM, Broome J, Luff N, Pelling M, Smith D: Acute mountain sickness susceptibility, fitness and hypoxic ventilatory response. Eur Respir J 1991; 4:1000-1003

8. Hackett PH, Rennie D: Acute mountain sickness. Semin Respir Med 1983; 5:132-140

9. Van Itallie TB: Health implications of overweight and obesity in the United States. Ann Intern Med 1985; 103(pt 2):983-988

10. Baecke JAH, Burema J, Frijters JER: A short questionnaire for the measurement of habitual physical activity in epidemiological studies. Am J Clin Nutr 1982; 36:936-942

11. Nederlandse Voedingsmiddlentabel, 32nd edition. Gravenhage, Voorlichtingsbureau voor de Voeding, 1979

12. Shapiro S, Weinblatt E, Frank CW, Sager RV: The H.I.P. study of incidence and prognosis of coronary heart disease: Preliminary findings on incidence of myocardial infarction and angina. J Chronic Dis 1965;18:527-558

13. Durnin JVGA, Passmore R: Energy, Work and Leisure. London, England, Heinmann Educational Books, 1967

14. Lake Louise Consensus on Definition and Quantification of Altitude Illness, *In* Sutton JR, Coates G, Houston CS (Eds): Hypoxia: Mountain Medicine. Burlington, Vt, Queen City Press, 1992, pp 327-330

15. Houston CS: Incidence of acute mountain sickness: A study of winter visitors to six Colorado resorts. Am Alpine J 1985; 59:162-165

16. Dean AG, Yip R, Hoffman RE: High incidence of mild acute mountain sickness in conference attendees at 10,000 feet altitude. J Wilderness Med 1990; 1:86-92

17. Ravenhill TH: Some experiences of mountain sickness in the Andes. J Trop Med Hyg 1913; 16:314-320

18. Menon ND: High-altitude pulmonary edema. N Engl J Med 1965; 273:66-73

19. Hirata K, Masuyama S, Saito A: Obesity as risk factor for acute mountain sickness (Letter). Lancet 1989; 2(8670):1040-1041

20. Goldsmith R, Hale T: Relationship between habitual physical activity and physical fitness. Am J Clin Nutr 1971; 24:1489-1493

21. Mundal R, Erikssen J, Rodahl K: Assessment of physical activity by questionnaire and personal interview with particular reference to fitness and coronary mortality. Eur J Appl Physiol 1987; 56:245-252

22. Sobolski J, Kornitzer M, De Backer, et al: Protection against ischemic heart disease in the Belgian physical fitness study: Physical fitness rather than physical activity? Am J Epidemiol 1987; 125:601-610

23. Kohl HW, Blair SN, Paffenberger RS Jr, Macera CA, Kronenfeld JJ: A mail survey of physical activity habits as related to measured physical fitness. Am J Epidemiol 1988; 127:1228-1239

24. Bouchard C, Shephard RJ, Stephens T, Sutton JR, McPherson BD: Exercise, Fitness, and Health, *In* Exercise, Fitness and Health: A Consensus of Current Knowledge. Champaign, Ill, Human Kinetics Books, 1990, pp 428

25. Wilson PWF, Paffenberger RS Jr, Morris JN, Havlik RJ: Assessment methods for physical activity and physical fitness in population studies: Report of a NHLBI workshop. Am Heart J 1986; 111:1177-1192

26. Leon AS, Jacobs DR Jr, DeBacker G, Taylor HL: Relationship of physical characteristics and life habits to treadmill exercise capacity. Am J Epidemiol 1981; 113: 653-660

27. Lamb KL, Brodie DA: Leisure-time physical activity as an estimate of physical fitness: A validation study. J Clin Epidemiol 1991; 44:41-52

28. Kannel WB, Soorlie PS: Some health benefits of physical activity: The Framingham study. Arch Intern Med 1979; 139:857-861

29. Magnus K, Matroos A, Strackee J: Walking, cycling, or gardening, with or without seasonal interruption, in relation to acute coronary events. Am J Epidemiol 1979; 110:724-733

30. Taylor HL, Jacobs DR Jr, Schucker B, Knudsen J, Leon AS, Debacker G: A questionnaire for the assessment of leisure time physical activities. J Chronic Dis 1978; 31:741-755

31. Montoye HJ: Estimation of habitual physical activity by questionnaire and interview. Am J Clin Nutr 1971; 24:1113-1118

32. Bouchard C, Tremblay A, Leblanc C, Lortie G, Savard R, Thériault G: A method to assess energy expenditure in children and adults. Am J Clin Nutr 1983; 37:461-467

33. Paffenberger RS Jr, Wing AL, Hyde RT: Physical activity as an index of heart attack risk in college alumni. Am J Epidemiol 1978; 108:161-175

34. Laporte RE: An objective measure of physical activity for epidemiological research. Am J Epidemiol 1979; 109:158-168